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AN APPARATUS FOR AUTOMATICALLY CHANGING THE TEMPERATURE OF A CHAMBER

GEORGE F. POTTER

It has been shown that the injury produced in certain plant tissues by freezing is influenced considerably by the rate at which the temperature falls during the freezing process.[1] In order to obtain a uniform and known rate of temperature fall for experiments of this sort, the writer has developed an apparatus in which the *rate of temperature change* is automatically controlled by clockwork. Any desired rise or fall of temperature can be obtained, the conditions desired for a ten-hour period being determined and recorded in advance. By repeating the experiment without altering the adjustments, different lots of tissues may be frozen under duplicate temperature conditions.

A longitudinal section of the freezing chamber, together with end, top, and side views of the controlling mechanism are shown in Plate I. Details of certain portions of the apparatus, as indicated by lettering analogous to that used in Plate I, are shown in both front and side view in Plate II. The freezer proper consists of three cylindrical galvanized iron cans, placed one within the other, riveted together, and packed in a box of sawdust for insulation. The freezing mixture is placed in the space between the two outside cans (*a*, Plate I). The innermost can (*c*, Plate I) is the freezing chamber. The intervening space (*b*, Plate I) is used as an air space to prevent too rapid cooling unless temperatures lower than—10° C. are desired, in which case it is filled with an additional quantity of ice and salt. The two outside chambers (*a* and *b*, Plate I) are fitted with pipes and stopcocks for drawing off the brine. The opening through these must be straight to facilitate removing obstructions.

The freezing chamber is fitted with a tight galvanized iron cover, to the center of which a short section of iron pipe is attached firmly by means of an iron collar. All thermometers, recording and control apparatus are introduced through this opening. A steel T-bar is securely clamped to the iron pipe (section *BB*, Plate II) and extends from slightly above the top of the pipe to within a few inches of the bottom of the chamber. This bar serves as a support for both fan shaft and thermostat, and by means of clamps holds interchangeable racks to which the experimental materials are attached. All three cans are covered by a single galvanized iron cover of circular shape insulated with cork board. The iron pipe from the inner chamber passes through an opening in the exact center of the insulated cover, which is therefore free to revolve about the pipe. Ice and salt may be placed in any part of the two outer spaces (*a* and *b*, Plate I), through an opening near the outer edge of this cover.

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[1] Chandler, W. H. Killing of plant tissue by low temperature. Mo. Agric. Exp. Sta. Research Bull. **8**: 199–205. 1913.

In such a chamber it is always difficult to keep the temperature uniform from top to bottom. To accomplish this as nearly as possible, a false wall or tin cylinder about two inches smaller in diameter than the freezing chamber, is introduced and held in place with wooden blocks (longitudinal section of freezer, Plate I). The cold wall of the chamber outside and the heating coil within cause the air to circulate upward inside the false wall and downward outside it. In addition, the circulation is forced by a fan at the bottom of the chamber. When one is freezing parts of plants that do not obstruct the passage of air, thermometer readings indicate that there is less than 0.1° C. difference in temperature over a vertical distance of eight inches.

The heating coil is wound with about 30 feet of no. 30 "Chromel C" resistance wire, having a total resistance of about 200 ohms. As a rule a large low-resistance lamp, or two 40-watt lamps in parallel, are placed in series with the coil to reduce the amount of heat given off and to act as a pilot light. On a 110-volt A. C. lighting circuit about one half ampere or less of current is used. The lamp can be switched out of the circuit if more heat is needed, as for instance when a large quantity of freezing mixture has just been added. An ordinary "Dim-a-lite" or "Hylo" connection is also placed in the circuit and can be used to reduce the amount of heat given off by the coil, as for instance when the ice is nearly exhausted. These adjustments are frequently convenient, although not necessary for the operation of the machine.

A mercury thermostat (*C*, Plate II) controls the heating coil by means of a telegraphic relay operating on current from two dry cells. When the machine is operated continuously it is necessary to have two batteries of two cells each. One battery may then recuperate while the other is in use. The connection is conveniently alternated by means of a double throw switch. The thermostat consists of a piece of capillary tubing sealed to a bulb containing mercury. An enlargement at the top of the capillary holds the excess mercury at temperatures above the working range. The thermostat used by the writer has a bulb about 1 cm. in diameter by 13 cm. in length and contains sufficient mercury to cause the mercury in the capillary to rise or fall about 2 mm. for each degree Centigrade change of temperature. Electric connection is made between the mercury in the bulb and that in a side arm by means of a platinum wire sealed in the side of the bulb (*C*, Plate II). A platinum wire guided to the exact center of the capillary by a small glass rod makes contact at the top of the mercury column (*CC*, Plate II). The guide is indispensable for accurate results because it makes an appreciable difference in temperature whether contact is made at the center or at the edge of the convex meniscus. An insulated wire is run from the battery to the side arm. The metal parts of the apparatus acting as a ground wire carry the current to the contact in the capillary. A condenser is used to prevent sparks at the point of contact with the mercury, and to eliminate the arc completely it is necessary to short circuit the terminals of the condenser through a resistance of about 700 ohms. A fifteen-watt Mazda bulb is used for this purpose.

The point at which the platinum wire touches the mercury in the capillary tube controls the temperature at which the heating coil is brought into use, and hence controls the temperature of the chamber. The contact wire is attached to a plunger, which moves vertically in guides fastened to the T-bar above the thermostat (longitudinal section, Plate I, and *B* and *C*, Plate II). The mechanism which actuates this plunger is similar in principle to a recording thermometer (*E*, *F*, and *G*, Plate I). The hands were removed from a "Big Ben" alarm clock and a shaft, bearing a drum three inches in diameter and four inches long, was soldered to the hour-hand shaft. A time-temperature chart is attached to the drum, degrees being marked by equal spaces along the axis of the cylinder, and hours by twelve equal spaces about its circumference. The distance to be laid off for each degree depends on the sensitivity of the thermostat and on the relative lengths of the two levers which will be referred to as the "long arm" and "short arm" of the "revolving shaft." The time-temperature curve is constructed with a flexible lead bar, fastened at each end by a clamp (*e*) sliding in a groove which runs lengthwise of the drum (*F* and *G*, Plate I). Below the drum and at right angles to it there is a revolving shaft (*E*, Plate I). At the clockwork end of this shaft a long arm, somewhat similar to that which carries the recording pen of the thermograph, extends upward and engages the lead bar with a small connecting pin (*E* and *G*, Plate I). At the other end of the shaft, which is pivoted in a bearing at the top of the T-bar leading down into the freezing chamber, there is a short arm which is joined by means of a connecting rod to the plunger carrying the platinum contact wire of the thermostat (*A* and *B*, Plate II). The weight of the connecting rod and plunger acting on the short arm as a lever tends to revolve the shaft and thus keeps the connecting pin of the long arm in contact with the edge of the lead bar. As the drum revolves, a movement of the long arm is permitted in accordance with the curve traced by the lead bar, and a proportionate movement is transmitted to the plunger and contact point of the thermostat through the turning of the shaft and through the resulting movement of the short arm and connecting rod. The short arm is attached to the shaft in such a way that it forms a right angle with the connecting rod when the long arm is at right angles to the axis of the drum. The vertical movement of the plunger is therefore always exactly proportionate to the horizontal distance which the long arm moves along the axis of the drum, although the amount that the shaft revolves for each degree of temperature is greater as the arm approaches either end of the drum.

Regulation of the apparatus is accomplished by means of an adjusting screw at the top of the connecting rod (*A*, Plate II). The temperature within the chamber is read with a thermometer. The drum is revolved until the long arm indicates the same temperature on the chart. The screw is then turned until the platinum point just makes a contact with the mercury in the capillary. In making this adjustment it is necessary to allow for some "lag" in the thermostat if temperatures are changing rapidly in the chamber and if the thermometer used is a sensitive one. As a rule the apparatus is held about fifteen minutes at the adjusting temperature. In operation, the "lag," using the large thermostat mentioned above, did not cause variations in temperature of more than 0.25° C. when the temperature of the chamber was changing at a rate of 16° C. per hour.

The connecting rod is so designed that it may be lifted up and detached from its support on the short arm of the revolving shaft. The base of the clock mechanism is fastened to a slotted support by a screw clamp. By detaching the connecting rod and loosening the clamp, shaft and clock can be removed. The insulated wire leading to the thermostat is then disconnected from its binding post and the covers of the freezing chamber may be removed.

The use of this machine has enabled the writer to perform freezing experiments under conditions controlled more accurately than has been possible even with the closest personal attention when using a hand-controlled freezer. The range and accuracy of regulation of temperature depend almost entirely upon the thermostat. The instrument used by the writer works through a range of 10° C., and the variations between the temperature indicated on the chart and that observed in the chamber usually are not greater than 0.1° C., although sometimes variations of 0.25° C. are observed. A less sensitive thermostat capable of working through a correspondingly greater range of 40° C. showed maximum variations of about 0.5° C. However, if particles of mercury become separated from the top of the column in the capillary tube, the operation of the machine becomes unreliable and usually the temperature of the chamber becomes too high. To avoid this the capillary must be cleaned of any oil or dirt about once a week, or sometimes oftener if foreign materials chance to enter. *It is also necessary to keep the glass guiding rod of the contact point (CC, Plate II) above the surface of the mercury because if immersed it breaks the column,* carrying part of the mercury up above the rod. It is possible that this difficulty could be eliminated by the use of some other type of thermostat, but the writer has not been able to find one which has the same sensitivity, and at the same time the ability to return accurately to the original starting point after going through wide temperature variations. The last mentioned characteristic is absolutely essential for the operation of a machine of this sort. Even with these limitations the machine enables the experimenter to do much more accurately controlled work than would be possible without it. The writer's record book shows a total of 74 experiments performed in February and March, 1919. Seven of these were of at least 48 hours duration, about half of the remainder 12 hours, and none less than 6 hours. Most of the time one short experiment was carried on during the day, and one of twelve or more hours' duration was run during the night. Out of the total, seven were discarded because the final temperature was more than 0.25° C. from that desired.

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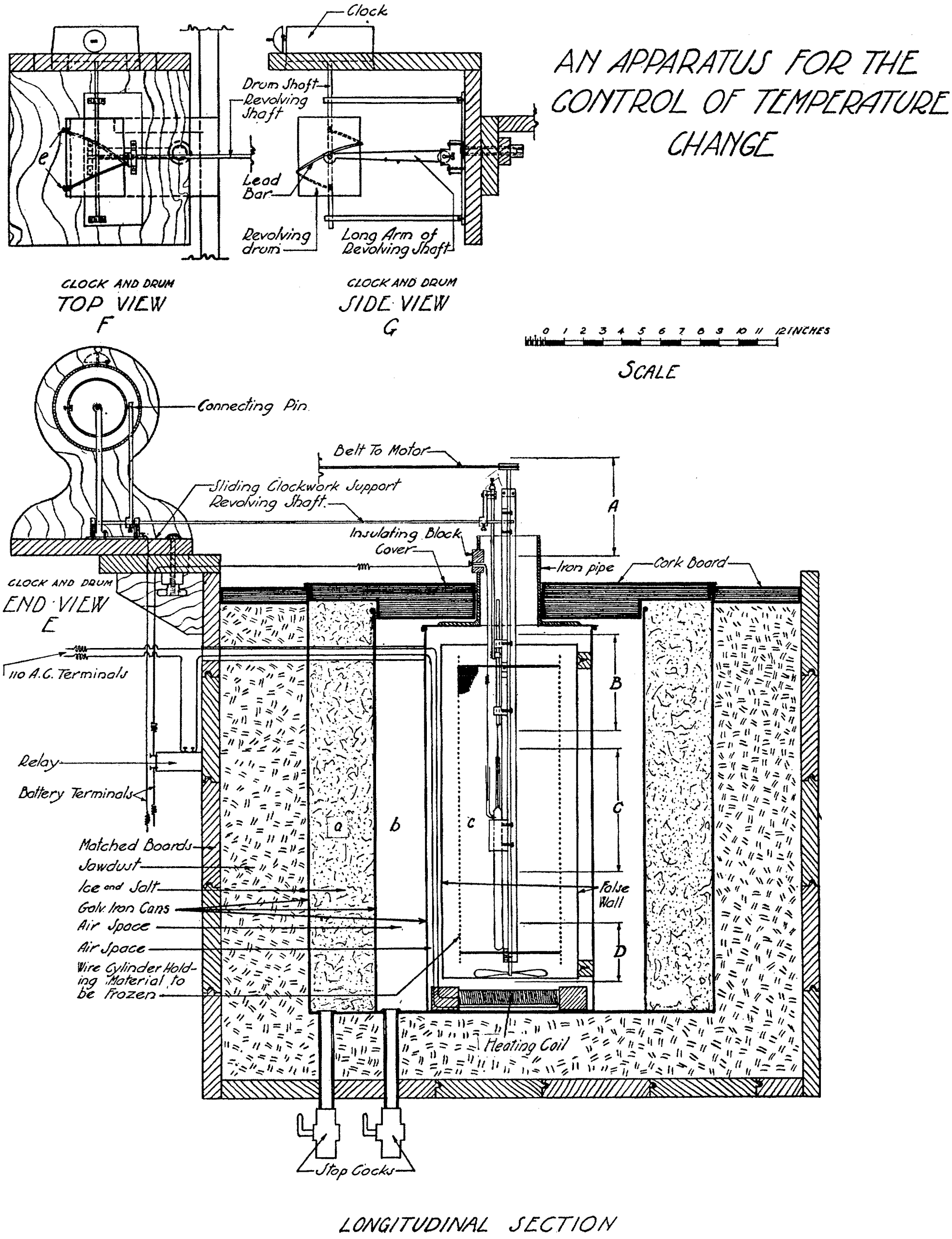

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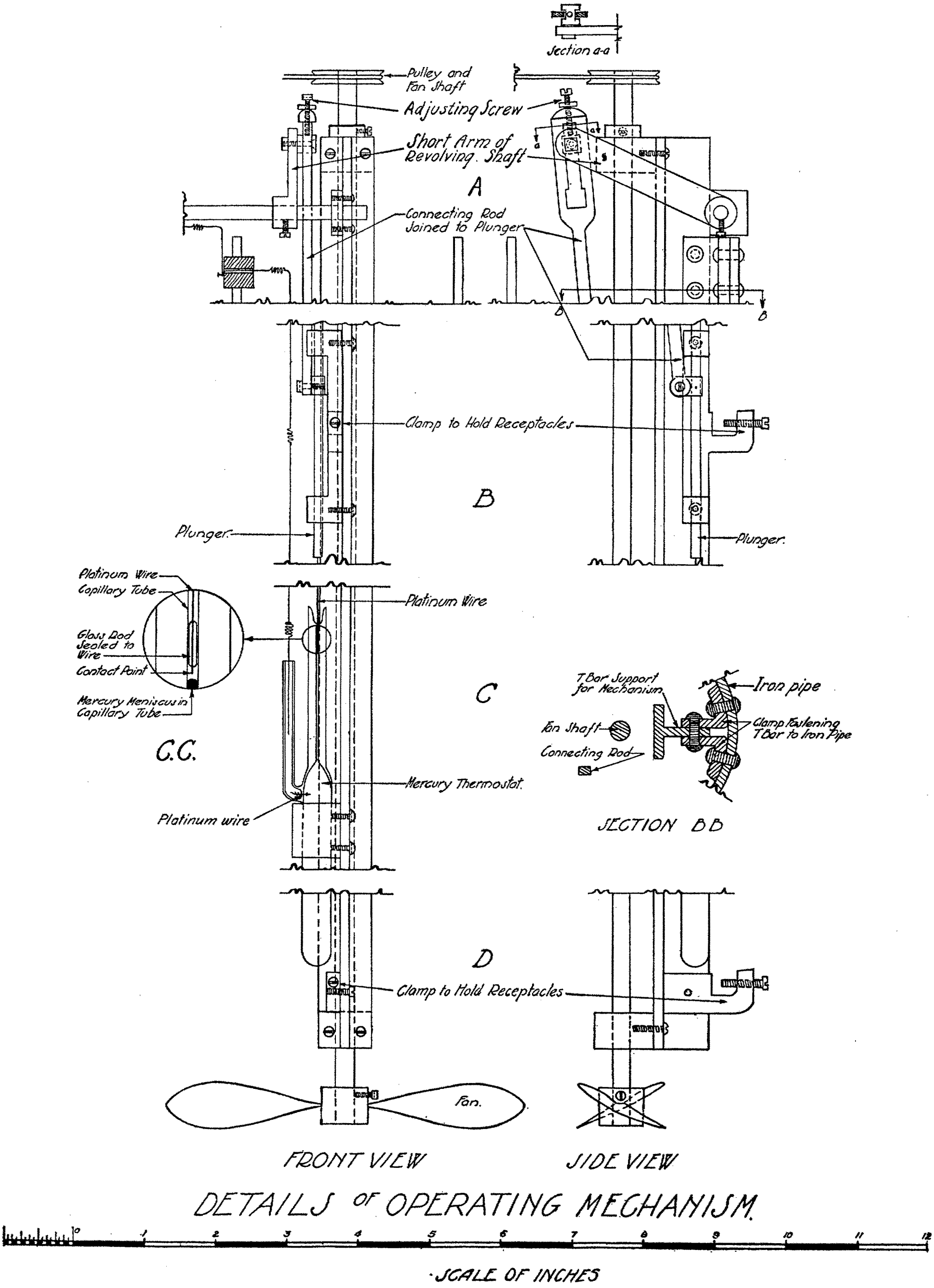

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